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# Noninvasive Visualization of the Cardiac Venous System Using Multislice Computed Tomography

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**OBJECTIVES** We sought to evaluate the value of multislice computed tomography (MSCT) to depict the cardiac venous anatomy.

**BACKGROUND** During cardiac resynchronisation therapy (CRT), left ventricular (LV) pacing is established by a pacemaker lead in a tributary of the coronary sinus (CS). Knowledge of the CS anatomy and variations may facilitate the implantation of LV leads.

**METHODS** The MSCT scans of 38 patients (34 men; age 60 ± 12 years) were studied. Anatomical variants were divided in three groups, dependent on the continuity of the cardiac venous system at the crux cordis. The CS ostium and distances between the main tributaries were measured.

**RESULTS** The most frequently observed variant had a separate insertion of the CS and the small cardiac vein in the right atrium (24 patients [63%]). In 11 patients (29%), there was continuity of the anterior and posterior venous system at the crux cordis. In three patients (8%), the posterior interventricular vein (PIV) did not connect to the CS. The mean distance from the PIV to the posterior vein of the left ventricle (PVLV) was 42.4 ± 18.1 mm, from the PVLV to the left marginal vein (LMV) 39.9 ± 15.6 mm, and from the LMV to the anterior interventricular vein 45.4 ± 15.3 mm. The diameter of the CS ostium was 12.6 ± 3.6 mm in anteroposterior and 15.5 ± 4.5 mm in the superoinferior direction ($p < 0.01$).

**CONCLUSIONS** The anatomy of the CS and its tributaries can be evaluated using MSCT. As substantial variation in anatomy was observed, pre-implantation knowledge of the venous anatomy may help to decide whether transvenous LV lead placement for CRT is feasible. (J Am Coll Cardiol 2005;45:749–53) © 2005 by the American College of Cardiology Foundation

In cardiac resynchronization therapy (CRT), left ventricular (LV) pacing is achieved by positioning the LV lead in one of the tributaries of the coronary sinus (CS). Although the success rate for transvenous LV lead placement is relatively high (88% to 95% in large clinical trials), in 5% to 12% of patients, the procedure does not succeed (1), and these numbers may be higher in inexperienced centers. Failure of LV lead placement has been attributed to the inability to insert catheters in the CS and the lack of suitable side branches (1,2). Knowledge of the cardiac venous anatomy before these procedures may facilitate LV lead positioning. In addition, it has been demonstrated that the success of CRT is related to the ability to improve ventricular function by lowering the degree of dyssynchrony (1). However, the optimal pacing site with respect to dyssynchrony improvement (site of latest activation within the LV) may not always have a suitable vein. In this case, a surgical approach may be preferred (2,3).

Multislice computed tomography (MSCT) has become an important tool for noninvasive evaluation of cardiovascular structures (4). However, no data are currently available on the use of MSCT to visualize the coronary venous anatomy. The aim of this study was to evaluate the feasibility of MSCT to depict the venous drainage system of the heart: the CS and its tributaries.

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## METHODS

**Study population.** The anatomy of the cardiac venous system was studied in 38 patients (34 men; age 60 ± 12 years) in whom MSCT scanning was performed for noninvasive evaluation of coronary artery disease (n = 18), evaluation of the pulmonary veins before radiofrequency catheter ablation of atrial fibrillation (n = 10), and in 10 patients with severe heart failure (mean LV ejection fraction 29 ± 5%) and who are considered for CRT. Three patients had a pacemaker.

**MSCT.** This imaging method was performed with a 16-slice Toshiba Multislice Aquilion 0.5 system (Toshiba Medical Systems, Otawara, Japan). Nonionic contrast material (Xenetix 300, Guerbet, Aulnay S. Bois, France) was used. Scanning was performed using simultaneous acquisition of 16 sections with a collimated slice thickness of 0.5 mm. The helical pitch was 4 mm/0.5 s, rotation time was 400 to 600 ms, and tube voltage was 120 kV at 250 mA. A segmental reconstruction algorithm allowed inclusion of patients with a range of heart rates without the need for pre-oxygenation or beta-blocking agents. Retrospective electrocardiographic (ECG) gating was performed to eliminate cardiac motion artefacts. Data reconstruction was performed on a Vitrea post-processing workstation (Vital

**Abbreviations and Acronyms**

CS = coronary sinus
CRT = cardiac resynchronization therapy
LMV = left marginal vein
LV = left ventricle
MSCT = multislice computed tomography
PIV = posterior interventricular vein
PVLV = posterior vein of the left ventricle
RA = right atrium

Images, Plymouth, Minnesota). The scans were evaluated in consensus by two observers.

**Anatomic observations.** The anatomy of the CS and its tributaries was studied in relation to the crux cordis. The tributaries of the cardiac venous system (Fig. 1A) were identified on volume-rendered reconstructions. Thereafter, the course of the veins was evaluated in three orthogonal planes and using multiplanar reformatting. Each patient was designated to one of three groups of variable anatomy (modified after Von Ludinghausen) (Fig. 1B) (5), as follows: Variant 1—continuity of the cardiac veins at the crux cordis. The small cardiac vein connects to the CS at the crux cordis; variant 2—small cardiac veins and/or anterior cardiac veins enter the right atrium (RA) independently from the CS. The posterior interventricular vein (PIV) connects to the CS at the crux cordis; variant 3—disconnection between the CS and PIV. The PIV is connected to the small cardiac vein or enters the RA independently.

**Quantitative data.** The ostium of the CS was defined as the site where the CS makes an angle with the RA. Multiplanar reformatting was used to determine the size of the ostium in two directions (Fig. 1C). The distance between the ventricular tributaries was measured on volume-rendered reconstructions (Fig. 1D).

**Statistical analysis.** Continuous data are expressed as mean values and corresponding standard deviations. Dichotomous data are expressed as numbers and percentages. The paired Student *t* test was used to evaluate differences in diameters of the ostium of the CS in anteroposterior and superoinferior direction. A value $p < 0.05$ was considered significant.

## RESULTS

**Anatomic observations.** The cardiac venous system was visualized in all patients. Although the CS and PIV were observed in all patients, the posterior vein of the LV (PVLV) and the left marginal vein (LMV) were observed in 36 (95%) and 23 (61%) patients, respectively. A small cardiac vein was present in 17 patients (45%).

**Variants in anatomy.** Continuity of the CS with the small cardiac vein was observed in 11 patients (29%) (variant 1). In 21 patients (55%), the small cardiac vein was not found. In 24 patients (63%), the PIV connected to the crux cordis (variant 2), and in 3 patients (8%), the PIV was not connected to the CS at the crux cordis, but entered the RA separately (variant 3). Examples of anatomic variations are demonstrated in Figure 2. The vein of Marshall was distinguished in 13 patients (34%). Anatomical observations are summarized in Table 1.

**Table 1.** Anatomic Observations

| | No HF (n = 28) | HF (n = 10) |
|---|---|---|
| Coronary sinus | 28 (100%) | 10 (100%) |
| Small cardiac vein | 13 (46%) | 4 (40%) |
| Posterior interventricular vein | 28 (100%) | 10 (100%) |
| Posterior vein of left ventricle | 27 (86%) | 9 (90%) |
| Left marginal vein | 16 (57%) | 7 (70%) |
| Vein of Marshall | 10 (36%) | 3 (30%) |
| Posterior branches | 9 (32%) | 4 (40%) |
| Variant 1 | 8 (29%) | 3 (30%) |
| Variant 2 | 18 (64%) | 6 (60%) |
| Variant 3 | 2 (8%) | 1 (10%) |

HF = heart failure.

**Quantitative data.** Interindividual variation was observed in the distances between the main tributaries draining the LV. No significant differences were observed in patients with as compared with patients without heart failure. In four patients, the distance between the PIV and PVLV was $\leq$2 cm. Two of these patients also lacked the presence of LMV. The mean diameter of the LMV was quite small, with an average of only $3.9 \pm 1.9$ mm. The diameter of the LMV was significantly larger in patients with as compared with those without heart failure.

The mean diameter of the ostium of the CS in the anteroposterior direction was $12.6 \pm 3.6$ mm. In the superoinferior direction, the diameter of the ostium was significantly larger ($15.5 \pm 4.5$ mm, $p < 0.01$), indicating an asymmetrical shape of the ostium, with the long axis in the superoinferior direction.

There were no significant differences in diameters of the ostia in patients with as compared with those without heart failure ($p = 0.05$). Quantitative data are summarized in Table 2.

## DISCUSSION

The results of this study demonstrate an interindividual variation of the cardiac venous system in: 1) insertion and continuity of the main tributaries; 2) the number of antero/posterolateral tributaries; and 3) the distance between the main tributaries. To date, only few anatomic reports provide a detailed description of the cardiac venous anatomy (5). Our study is the first to describe variations in cardiac venous anatomy using MSCT.

Not only the lack of suitable side branches but also obstruction and ostial narrowing (e.g., by a thebesian valve) may complicate LV lead implantation (1,2,6). In the current study, a left marginal vein was not observed in 15 patients (39%). In two of these patients, the PVLV already branched

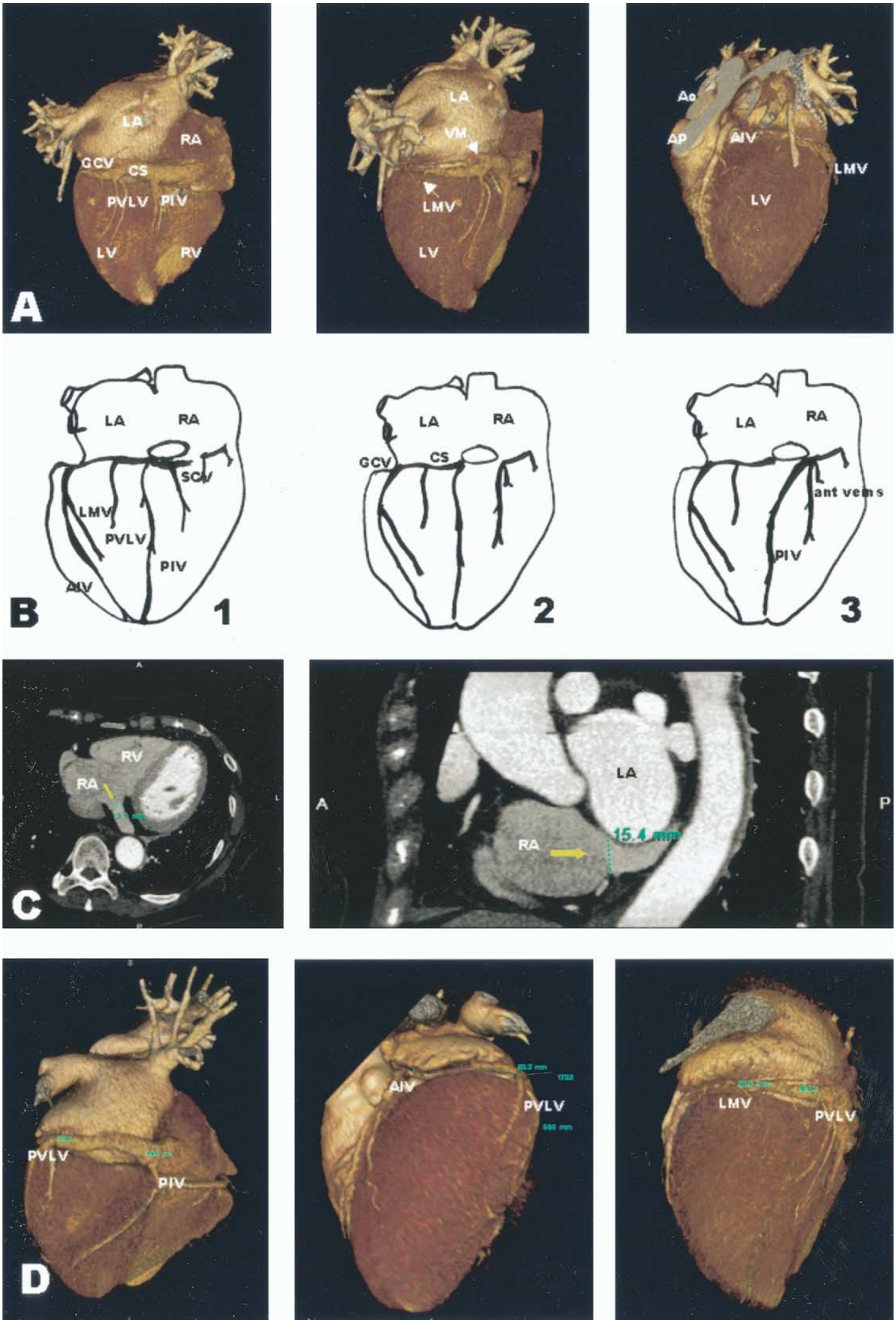


**Figure 1.** The cardiac venous system. **(A)** The border of the coronary sinus (CS) is marked by the vein of Marshall (VM). The CS continues in the great cardiac vein (GCV), which continues anteriorly in the anterior interventricular vein (AIV). As seen from the right atrium (RA), the first tributary of the CS is the posterior interventricular vein (PIV). The next tributaries are the posterior vein of the left ventricle (PVLV) and left marginal vein (LMV). **(B) Left** = variant 1; **middle** = variant 2; **right** = variant 3. See text for explanation. **(C) Left** = the CS ostium measured in the anteroposterior direction; transverse plane; **right** = the CS ostium in superoinferior direction; coronal plane. **(D)** Measurement of the distances between the different tributaries of the cardiac venous drainage system. Ant = anterior; AP = pulmonary artery; Ao = aorta; LA = left atrium; LV = left ventricle; RV = right ventricle.

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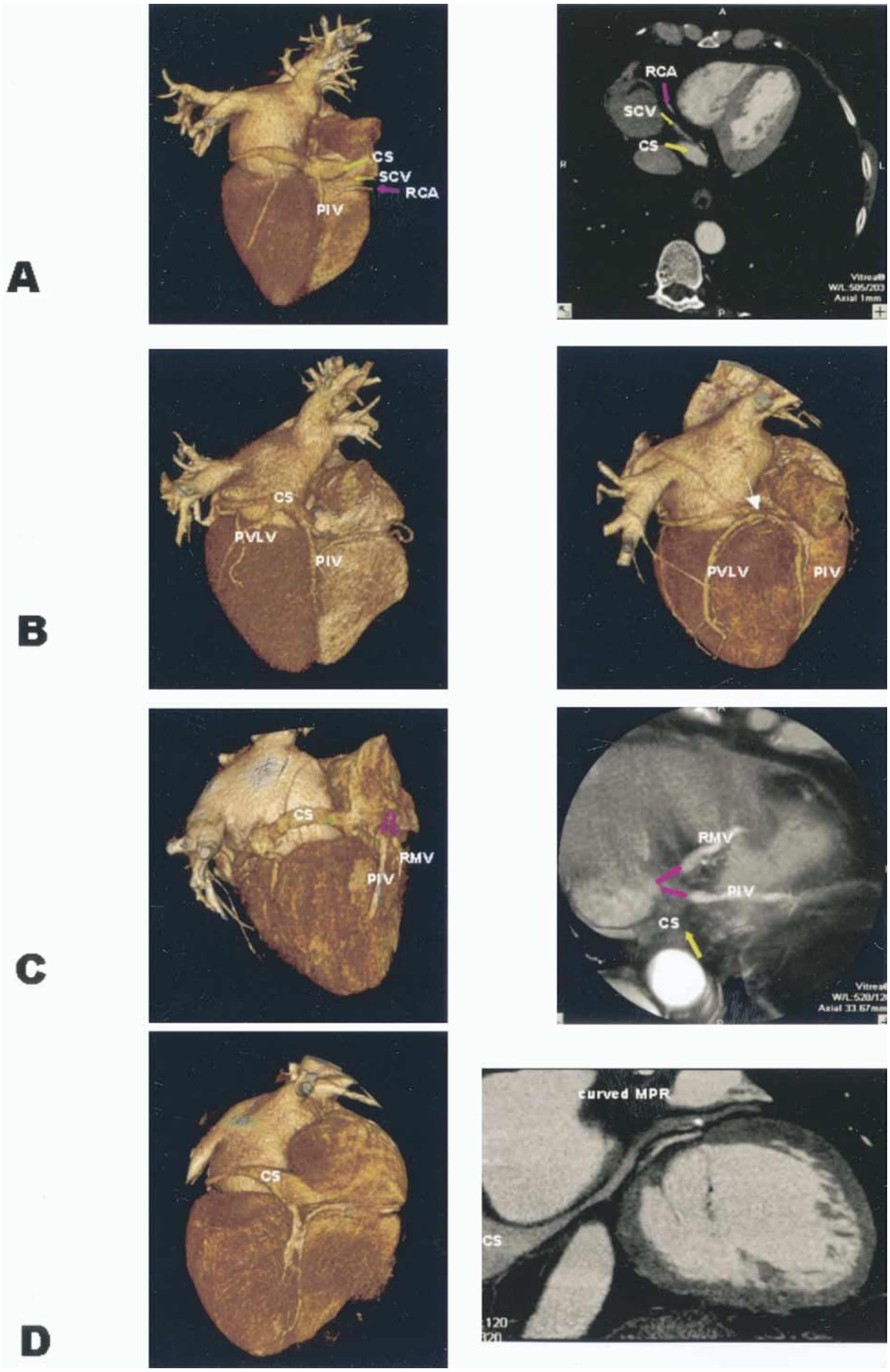


**Figure 2.** **(A)** Variant 1. **Left** = volume-rendered reconstruction. The CS, PIV, and small cardiac vein (SCV) are continuous at the crux cordis. The SCV **(lower yellow arrow)** runs in close association with the right coronary artery (RCA) **(purple arrow)**. **Right** = the CS and SCV **(yellow arrows)** and RCA **(purple arrow)** on the transverse plane. **(B)** Variant 2. The CS enters the RA independently from the anterior cardiac veins. **Right** = the ostia of the CS, PIV, and PVLV are confluent and form a large common ostium **(arrow)**. **(C)** Variant 3. **Left** = the PIV is not connected to the CS, but enters the RA independently, as is also demonstrated on the transversal orthogonal plane in the right panel. The **purple arrows** indicate the PIV and a right marginal vein (RMV); the **yellow arrow** indicates the CS. **(D)** This MSCT scan is of a patient who, besides the PIV, lacks CS tributaries. Although the ostium is rather large, more distal from the ostium, the CS narrows, as demonstrated on a volume-rendered reconstruction **(left panel)** and on a curved multiplanar reformatting **(right panel)**. Abbreviations as in Figure 1.

within 2 cm from the crux cordis without additional side branches. The small cardiac vein was observed in 45%, slightly more than described by Von Ludinghausen (5). In particular, the identification of patients who lack the presence of posterolateral branches with a sufficient diameter to allow passage of a catheter or pacemaker lead may have

**Table 2.** Quantative Data

| | No HF | HF |
|---|---|---|
| Ostium CS, anteroposterior (mm) | 11.9 ± 3.5 | 14.4 ± 3.4 |
| Ostium CS, superoinferior (mm) | 14.7 ± 4.4* | 17.9 ± 4.0* |
| LMV diameter (mm) | 2.6 ± 1.1 | 5.4 ± 1.4† |
| PIV–PVLV distance (mm) | 44.6 ± 17.4 (range 13.9–76.4) | 35.9 ± 19.5 (range 6.1–59.6) |
| PVLV–LMV distance (mm) | 37.7 ± 14.6 (range 14.6–68.3) | 45.8 ± 17.9 (range 21.0–64.6) |
| PVLV–AIV distance (mm) | 77.6 ± 18.3 (range 50.3–122.7) | 83.0 ± 29.9 (range 40.3–117.1) |
| LMV–AIV distance (mm) | 44.9 ± 16.4 (range 17.4–77.2) | 46.5 ± 14.1 (range 15.5–57.7) |

*$p < 0.01$ as compared with the diameter in the anteroposterior direction. †$p < 0.01$ as compared with patients without HF. Data are presented as the mean value ± SD.

AIV = anterior interventricular vein; CS = coronary sinus; HF = heart failure; LMV = left marginal vein; PIV = posterior interventricular vein; PVLV = posterior vein of the left ventricle.

implications for clinical practice. The variation in drainage patterns observed in the current study largely agrees with the results of anatomic studies (5). Observations from the current study also reveal a large variation in distances between the different side branches of the cardiac drainage system (Table 2). The finding that the CS ostium is ovally shaped agrees with observations in other cardiac veins (7).

The vein of Marshall can be used to mark the border between the CS and great cardiac vein (5). At this site, the valve of Vieussens is often present, which is an important cause of problems advancing the catheter into cardiac veins (8). In the current study, the vein of Marshall was observed in only 13 patients (34%). This finding is not surprising, as this structure is often obliterated by fibrosis.

**Clinical implications.** The MSCT may be used to identify complex patients who do not have additional side branches on the MSCT scan, and therefore may benefit more from an epicardial lead placement using a minimal invasive surgical approach. In addition, the site of latest LV activation, where the LV lead should ideally be positioned, can be evaluated for the presence of suitable venous anatomy preceding pacemaker implantation. Based on these findings, the clinician can decide beforehand whether a transvenous or minimally invasive approach for LV lead positioning is preferred.

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